(JP Application No. 149660/1998)

[Name of Document] SPECIFICATION

[Title of the Invention] PIEZOELECTRIC TRANSFORMER

[Claims]

[Claim 1] A piezoelectric transformer comprising a piezoelectric transformer element having a layered structure formed by alternately stacking a plurality of inner electrodes and a plurality of piezoelectric ceramics layers in a thickness direction, first electrodes formed on a side surface of said layered structure and connected to said internal electrodes, and at least one pair of second electrodes being formed in opposite each other on a side surface in areas different from those of said first electrodes and being kept at a same potential, and further comprising a circuit board for driving said piezoelectric transformer element, wherein said piezoelectric transformer element is mounted onto said circuit board, and each opposite electrode of said at least one pair of second electrodes and said circuit board being electrically connected each other.

[Claim 2] A piezoelectric transformer as claimed in claim 1, wherein a plurality of pairs of said second electrode are arranged in parallel to one another in the longitudinal direction, those electrodes in each pair of said second electrode being connected to output terminals having a same potential, and adjacent pairs of said second electrode being connected to said circuit board as output terminals different from each other.

[Claim 3] A piezoelectric transformer comprising a piezoelectric transformer element having a piezoelectric transformer body consisting of a layered structure formed by alternately stacking a plurality of inner electrodes and a plurality of piezoelectric ceramics layers or single piezoelectric ceramics layers, and output electrodes formed at one end of said piezoelectric transformer body, and further comprising a circuit board for driving said piezoelectric transformer element, said output electrode being provided with two terminals, said two terminals being electrically connected to said circuit board.

[Claim 4] A piezoelectric transformer as claimed in claim 3, wherein

said piezoelectric transformer body comprises a pair of input electrodes formed on a part of top and bottom opposite surfaces of said piezoelectric transformer body to be opposite to each other.

[Claim 5] A piezoelectric transformer as claimed in any one of claims 1 to 4, wherein said piezoelectric transformer element and said circuit board are electrically connected by at least one of a lead wire or a FPC.

[Claim 6] An inverter power supply for using a piezoelectric transformer as claimed in any one of claims 1 to 5.

[Detailed Description of the Invention]

[0001]

[Field of the Invention]

This invention relates to a piezoelectric transformer used in an inverter circuit or an adapter power supply circuit for a cold cathode tube as a backlight of a liquid crystal display panel in a notebook-type personal computer or a car-navigation system, a high voltage generating circuit for an electronic copying machine, and the like and, particularly, to a structure of an output electrode and mounting of such a transformer onto a circuit board.

[0002]

[Prior Art]

Conventionally, there is known the piezoelectric transformer element as shown in Fig. 6. The piezoelectric transformer shown in Fig. 6 is described as modified Rosen-type piezoelectric transformer element in the description hereinafter. The piezoelectric transformer element 50 comprises a layered structure 53 formed by alternately stacking inner electrode 57 and piezoelectric ceramics layers. An approximate half of the layered structure in its longitudinal direction is used as an input portion 51 while the other half is used as an output portion 52. In the input portion 51, every adjacent ones of the inner electrodes alternately stacked with the piezoelectric ceramics layers are extended or led to different side surfaces opposite to each other and connected to input electrodes 53a and 53b formed on the side surfaces of the layered structure 53, respectively. On the other hand, the output portion 52 comprises strip-like electrodes 58 arranged in parallel in the longitudinal direction of the layered

structure and alternately stacked with the piezoelectric ceramics layers. Both sides of these electrodes 58 are exposed at the opposite side surfaces and connected to a pair of output electrodes 53a and 53b, 54a and 54b, 55a and 55b, respectively, which are formed on the opposite side surfaces, respectively, and is opposite to each other.

[0003]

Regarding an electrical connection of the piezoelectric transformer element shown in Fig. 6 and the circuit board, the input electrodes 53a and 53b are provided with lead wires 53c and 53d connected to an input side. The output electrodes 54a, 55b, and 55a are provided with lead wires 54c, 55c, and 56c connected to an output side. One of the lead wires 56c of the output portion 52 has a high potential while the lead wires 54c and 56c have a low and a same potential.

[0004]

Furthermore, regarding a terminal structure and the electrical connection of the output portion 52, the lead wires 54c, 55c, and 56c are connected with the circuit board, respectively.

[0005]

A piezoelectric transformer element as shown in Fig. 7 is called as Rosen-type piezoelectric transformer element, and well known as well as the piezoelectric transformer in Fig. 6. As shown in Fig. 7, the piezoelectric transformer element 60 comprises a rectangular piezoelectric ceramic plate 63, electrodes 64 and 65 formed on top and bottom surfaces thereof over an approximate half in its longitudinal direction, and an electrode 68 formed on an end surface where the electrodes 64 and 65 are not formed. In the piezoelectric transformer element 60 having such a structure, lead wires 66 and 67 respectively connected to the electrodes 64 and 65 serve as an output terminal of an output portion 62. Lead wires connected to the electrode 68 serves to be kept at a high potential.

[0006]

[Problems to be Solved by the Invention]

However, a widened range of luminance control has been required to be

processed for an inverter utilizing the piezoelectric transformer, which may often adopts burst adjustment of brightness increasingly so as to meet the requirement. This results in a problem of generation of an audible sound, which has not occurred in a conventional mounting method. The reason is as follows. The vibration of the piezoelectric transformer has traditionally been excited in a single vibration mode in most cases. However, by addition of the brightness adjusting function, the vibration of the piezoelectric transformer is no longer a single mode vibration and thereby affects electrical junctions thereof.

[0007]

In addition to the problem that the vibration mode is no longer a single mode vibration, there is another problem due to transition into a small and thin device of the piezoelectric transformer element in which an area is limited for electrical connection upon an electrode structure thereof, thereby resulting in a problem in reliability of electrical connection between the piezoelectric transformer element and the circuit board.

[0008]

It is a technical object of the present invention to provide a piezoelectric transformer which can reduce a sound pressure level of an audible sound without deteriorating electric characteristics such as a step-up ratio and heat generation, and can improve reliability.

[0009]

It is another technical object of the present invention to provide a piezoelectric transformer which can realize a piezoelectric inverter being very thin in thickness.

[0010]

It is further technical object of the present invention to provide a piezoelectric inverter power supply utilizing the above-mentioned piezoelectric transformer.

[0011]

[Means for Solving the Problems]

According to the present invention, there is provided a piezoelectric transformer comprising a piezoelectric transformer element having a layered

structure formed by alternately stacking a plurality of inner electrodes and a plurality of piezoelectric ceramics layers in a thickness direction, first electrodes formed on a side surface of the layered structure and connected to the internal electrodes, and at least one pair of second electrodes being formed in opposite each other on a side surface in areas different from those of the first electrodes and being kept at a same potential, and further comprising a circuit board for driving the piezoelectric transformer element, wherein the piezoelectric transformer element is mounted onto the circuit board, and each opposite electrode of the at least one pair of second electrodes and the circuit board being electrically connected each other.

[0012]

According to the present invention, there is provided a piezoelectric transformer as claimed in claim 1, wherein a plurality of pairs of the second electrode are arranged in parallel to one another in the longitudinal direction, those electrodes in each pair of the second electrode being connected to output terminals having a same potential, and adjacent pairs of the second electrode being connected to the circuit board as output terminals different from each other.

[0013]

According to the present invention, there is provided a piezoelectric transformer comprising a piezoelectric transformer element having a piezoelectric transformer body consisting of a layered structure formed by alternately stacking a plurality of inner electrodes and a plurality of piezoelectric ceramics layers or single piezoelectric ceramics layers, and output electrodes formed at one end of the piezoelectric transformer body, and further comprising a circuit board for driving the piezoelectric transformer element, the output electrode being provided with two terminals, the two terminals being electrically connected to the circuit board.

[0014]

According to the present invention, there is provided a piezoelectric transformer as claimed in claim 3, wherein the piezoelectric transformer body comprises a pair of input electrodes formed on a part of top and bottom opposite

surfaces of the piezoelectric transformer body to be opposite to each other.

[0015]

According to the present invention, there is provided a piezoelectric transformer as claimed in any one of claims 1 to 4, wherein the piezoelectric transformer element and the circuit board are electrically connected by at least one of a lead wire or a FPC.

[0016]

According to the present invention, there is provided an inverter power supply for using any one of the above-mentioned piezoelectric transformer.

[0017]

[Mode of Embodying the Invention]

Description will be made about an embodiment of the present invention with reference to the drawings.

[0018]

Fig. 1(a) is a perspective view showing the piezoelectric transformer according to the first embodiment of the present invention. Fig. 1(b) is a sectional view taken along a line IB-IB in Fig. 1(a). Fig. 1(c) is a sectional view taken along a line IC-IC in Fig. 1(a).

[0019]

Referring to Fig. 1(a), (b) and (c), a piezoelectric transformer element 10 is an example of a modified Rosen type piezoelectric transformer element and comprises a layered structure 3 formed by alternately stacking rectangular inner electrodes 8 and strip-like connection electrodes 12, and piezoelectric ceramics layers 11. An approximate half of the layered structure 3 in a longitudinal direction serves as an input portion 1 and the other half serves as an output portion 2. The piezoelectric ceramics layers 11 are made of lead zirconate titanate. The connection electrode 12 is made of silver-palladium. Each of external electrodes is made of silver or silver-palladium.

[0020]

In the input portion 1, every adjacent ones of the inner electrodes 8 alternately stacked with the piezoelectric ceramics layers 11 are extended or led to different side surfaces opposite to each other and connected to the input

electrodes 4a and 4b formed on the side surfaces of the layered structure 3, respectively. The input electrodes 4a and 4b are provided with the lead wires 4c and 4d, respectively.

[0021]

On the other hand, the output portion 2 is provided with strip-like connection electrodes 8 arranged in parallel in the longitudinal direction of the layered structure 3 and alternately stacked with the piezoelectric ceramics layers 11. Both sides of these connection electrodes 8 are exposed at the opposite side surfaces of the layered structure 3 and connected to pairs of output electrodes 5a and 5b, 6a and 6b, 7a and 7b formed on the opposite side surfaces to be opposite to each other. The output electrodes 5a and 5b, 6a and 6b, 7a and 7b are connected to lead wires 5c and 5d, 6c and 6d, 7c and 7d, respectively. The output portion 2 has a high-voltage portion including the electrodes 6a and 6b. The electrodes 6a and 6b are electrically connected to each other. The electrodes 5a, 5b, 7a, and 7b in a low-voltage portion are similar in structure to the above-described electrodes 6a and 6b.

[0022]

Fig. 2 is a perspective view showing the state in which the piezoelectric transformer element in Fig. 1 is mounted onto the circuit board.

[0023]

The lead wires 5c and 5d, 6c and 6d, 7c and 7d, which are processed to have predetermined lengths, are soldered to eight points, i.e., the external electrodes 4a, 4b, 5a, 5b, 6a, 6b, 7a and 7b, respectively, of the piezoelectric transformer element 10 shown in Fig. 1. Next, by the use of a silicon adhesive via a silicon sheet, the piezoelectric transformer element 10 with leads connected is adhered to the circuit board 30 at the vibration nodes. The lead wires 5c and 5d, 6c and 6d, 7c and 7d are soldered to eight designated points on the circuit board 16. Herein, the lead wires are soldered in the first embodiment. Alternatively, a flexible printed circuit board (FPC) can also be soldered and connected.

[0024]

Fig. 3 is a circuit diagram of an inverter power supply utilizing the

piezoelectric transformer in Fig. 2.

[0025]

As shown in Fig. 3, the input-side lead wires 4c and 4d are connected to an input-side circuit 13. The output-side lead wires 6c and 6d are collected and are inputted through a single connection line 15 to one end of an output-side circuit. The output-side lead wires 5d and 7d are short-circuited. The output-side lead wires 5c and 7c are collected into a single connection line 16 which is inputted to the other end of the output-side circuit.

[0026]

In the piezoelectric transformer of the above-described structure according to the first embodiment of the present invention, the output portion 2 of the modified Rosen type piezoelectric transformer element 10 has an electrode structure in which the external electrodes of the output portion 2 are arranged on both sides as shown in Figs. 1(a), 1(b), and 1(c). The output side 12 of the piezoelectric transformer element has an internal structure as shown in Fig. 1(c). Electrical connection is established between the lead wires between 5c and 5d, between 6c and 6d, and between 7c and 7d. With this structure, the vibration of the piezoelectric transformer is symmetrical in the longitudinal direction so that the sound pressure of an audible sound can be reduced. In addition, the output portion 2 has two electrical connections at each part, i.e., the high-potential lead wires 6c and 6d and the low-potential lead wires 5c and 5d, 7c and 7d. Therefore, even if any trouble occurs at one of the electrical connections, there can be obtained the piezoelectric transformer which will not change in electrical characteristics.

[0027]

Next, the characteristics of the piezoelectric transformer element according to the first embodiment of the present invention are shown in following Table 1.

[0028]

Table 1

ITEM	EXISTING PRODUCT	PRODUCT OF PRESENT INVENTION
STEP-UP RATIO	90	91
DRIVING FREQUENCY (kHz)	64.5	64.5
HEAT GENERATION (℃)	18	17
AUDIBLE SOUND (dB)	70	62

Product of present invention: modified Rosen-type
(the first embodiment)

[0029]

As shown in Table 1, it is obvious that, in the modified Rosen type piezoelectric transformer element, the audible sound can be reduced by approximately 8dB, no degradation is observed in electrical characteristics such as a step-up ratio and heat generation, and the reliability is improved.

[0030]

Fig. 4 is a perspective view showing the piezoelectric transformer element according to the second embodiment of the present invention. The piezoelectric transformer element 20 shown in Fig. 4 is called a Rosen type. The transformer element 20 comprises a rectangular piezoelectric ceramic plate 63 with electrodes 64 and 65 formed on top and bottom surfaces of an approximate half of the plate in a longitudinal direction. On the other hand, an electrode 68 is formed on an end surface of the rectangular piezoelectric ceramic plate 63 at the side where the electrodes 64 and 65 are not formed. The transformer element is different from the conventional piezoelectric transformer element 60 shown in Fig. 7 in that the electrode 68 is provided with two lead wires 25 and 26. In the piezoelectric transformer element 20 of the

above-described structure, lead wires 66 and 67 connected to the electrodes 64 and 65 serve as input terminals of an input portion 62. The lead wires 25 and 26 connected to the electrode 68 are kept at a high potential.

[0031]

Fig. 5 shows the state in which the piezoelectric transformer element 20 in Fig. 4 is mounted on a circuit board 30. As shown in Figs. 4 and 5, the lead wires 66 and 67 are connected at two positions at the output side of the Rosen type piezoelectric transformer element 20. With this structure, it can provide a piezoelectric transformer in which the electrical characteristics do not changes even if the trouble has occurred at one position of the electrical connection.

[0032]

In the second embodiment of the present invention, it is also found out that no degradation is observed in the electrical characteristics as compared with the existing technique and the reliability is improved.

[0033]

[Effects of the Invention]

As described above, according to the embodiments of the present invention, it is possible to provide a piezoelectric transformer which has a symmetrical structure with respect to the vibration of the piezoelectric transformer so that the sound pressure level of the audible sound, which has been an outstanding problem, can be reduced, no degradation is observed in the electrical characteristics, and the reliability can be improved.

[0034]

In addition, according to the present invention, it can be provided the piezoelectric transformer which can realize a piezoelectric inverter being very thin in thickness.

[Brief Description of Drawings]

[Fig. 1]

(a) A perspective view showing a terminal structure of a modified Rosen-type piezoelectric transformer element according to the first embodiment of the present invention.

(b) A sectional view taken along a line IB-IB in Fig. 1(a).

(c) A sectional view taken along a line IC-IC in Fig. 1(a), showing a section of a high voltage portion of an output side.

[Fig. 2]

A perspective view showing the state in which the modified Rosen-type piezoelectric transformer in Fig. 1 is mounted onto the circuit board.

[Fig. 3]

A wiring diagram of the modified Rosen-type piezoelectric transformer in Fig. 2.

[Fig. 4]

A perspective view showing a terminal structure of the piezoelectric transformer according to the second embodiment of the present invention.

[Fig. 5]

A perspective view showing the state in which the Rosen-type piezoelectric transformer in Fig. 4 is mounted onto the circuit board.

[Fig. 6]

A perspective view showing a terminal structure of a conventional modified Rosen-type piezoelectric transformer.

[Fig. 7]

A perspective view showing a terminal structure of a conventional Rosen-type piezoelectric transformer.

[Description of Reference Numerals]

1 an input portion
2 an output portion
3 a layered structure
4a, 4b an input electrode
5a, 5b, 6a, 6b, 7a, 7b an output electrode
4c, 4d, 5c, 5d, 6c, 6d, 7c, 7d a lead wire
10 a piezoelectric transformer element
11 a piezoelectric ceramics layer
12 a connection electrode
13 an input-side circuit
14 an output-side circuit

20 a piezoelectric transformer element

25, 26, 66, 67, 69 a lead wire

30 a circuit board

53a, 53b an input electrode

54a, 54b, 55a, 55b, 56a, 56b an output electrode

53c, 53d, 54c, 55d, 56c a lead wire

61 an input portion

62 a output portion

63 a rectangular piezoelectric ceramic plate

64, 65, 68 an electrode

[Name of Document] ABSTRACT

[Summary]

[Object] To provide a piezoelectric transformer which can reduce a sound pressure level of an audible sound without deteriorating electric characteristics such as a step-up ratio and heat generation, improve reliability, and realize a piezoelectric inverter being very thin in thickness.

[Solving Means] There is provided a piezoelectric transformer comprising a piezoelectric transformer element 10 having a layered structure 3 formed by alternately stacking a plurality of inner electrodes 8 and a plurality of piezoelectric ceramics layers 11 in a thickness direction, first electrodes 4a and 4b formed on a side surface of the layered structure 3 and connected to the internal electrodes 8, and at least one pair of second electrodes 5a, 5b, 6a, 6b, 7a and 7b being formed in opposite each other on a side surface in areas different from those of the first electrodes 4a and 4b and being kept at a same potential, and further comprising a circuit board for driving the piezoelectric transformer element, and the piezoelectric transformer element 10 is mounted onto the circuit board, and each opposite electrode of the at least one pair of second electrodes 5a, 5b, 6a, 6b, 7a and 7b and the circuit board are electrically connected each other.

[Selected Figure]

Fig. 1